Space Weather Technical Forecast

Issued on Sunday, 24 March 2024 at 01:08 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Further Minor/Moderate radio blackouts (R1/R2) likely. Current S2 conditions gradually reducing. Minor to Moderate geomagnetic storms (G1-G2) expected into days 1 and 2 (24-25 Mar) given likely CME and HSS arrival. Slight chance of a Strong geomagnetic storm (G3).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity recorded at GOES16 and 18 rose to become High, with a X1.1 flare from a broad region north of AR3614 at 23/0133UTC, with some contribution from a simultaneous flare from AR3615. AR3615 itself produced five M class flares over the past 24 hours, the highest being an M5.1 at 23/1352UTC. There are now six sunspots on the visible disc, with the small region emerging in the northwest quadrant numbered AR3621. AR3615 remains by far the largest and most complex group on the disc, showing top tier Fkc/Beta-Gamma-Delta complexity, continuing to display penumbral growth across the region, as well as a slight consolidating trend. Changes in other groups were minor by comparison.

The main activity observed on coronagraphs in the period was a large and complex halo Coronal Mass Ejection (CME) associated with the X1.1 flare and connected filament lift-off. This event was associated with a type II radio sweep (791 km/s) and was clearly visible in all imagery given a significant post eruptive arcade signature. Modelling of this CME suggest a likely impact with Earth late on the 24th or early on the 25th of March.

Solar Wind / Geomagnetic Activity: The solar wind at L1 measured by ACE and DSCOVR were initially at background levels but steadily rose after 23/1200UTC as earth came into contact with the HSS in association with CH12 and are currently just about at elevated levels at 500km/s. The solar wind density has largely been above average, but became well above average at 23/1316UTC perhaps as a result of an approaching CIR region. The IMF saw a similar change from initial weak positive values giving way to weak to moderate broadly negative values which slowly rotate weakly positive again towards midday before becoming moderate to strong largely negative values, peaking at -14nT at 23/2012UTC. The phi angle showed was largely negative (towards the Sun).

The net result of the above solar wind measures was Unsettled to Active activity with a Moderate geomagnetic storm (Kp6) at 24/0000UTC.

Energetic Particles / Solar Radiation: GOES18 high energy (greater than 10MeV) proton flux rose following the X1.1 flare to rise above S1 levels from 23/0815UTC and above S2 levels at 23/1400UTC and remains elevated although has been on a gradual decline since 23/1800UTC.

High energy electron flux (greater than 2MeV) observed at GOES16 was at Normal Background levels. The observed 24-hour fluence was below the Active threshold, with a value at 24/0001UTC of 1.24e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Generally Moderate activity is expected, with further M-class flares likely from AR3615 and a slight chance of X-class flares. The most significant front side region (AR3615) remains present throughout the four days, with oncoming active regions in the northeast likely.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

The flare risk is held constant throughout the four days.

Solar Wind / Geomagnetic Activity: There is one Earth-directed CMEs in the current forecast, this is associated with the X1.1 flare a broad region north of AR3614 at 23/0133UTC. This produces a complex halo CME provisional modelled late on Day 1 (24 Mar) or early Day 2 (25 Mar), with winds perhaps increasing to 550-600km/s before slowly declining. The other notable enhancement is from the continuing connection CH12/-, maintaining Slightly Elevated to Elevated solar winds (450-500km/s) before beginning to ease through Day 3 (26 Mar) and returning to background levels by Day 4 (27 Mar).

Geomagnetic activity initially Unsettled to Active with a chance of G1-G2 intervals early Day 1 (24 Mar) due to coronal hole effects. Either late on Day 1 (24 Mar) or early Day 2 (25 Mar) further G1-G2 minor to moderate geomagnetic storm intervals are expected with a chance of G3 strong geomagnetic intervals, given the expected arrival of the above CME.

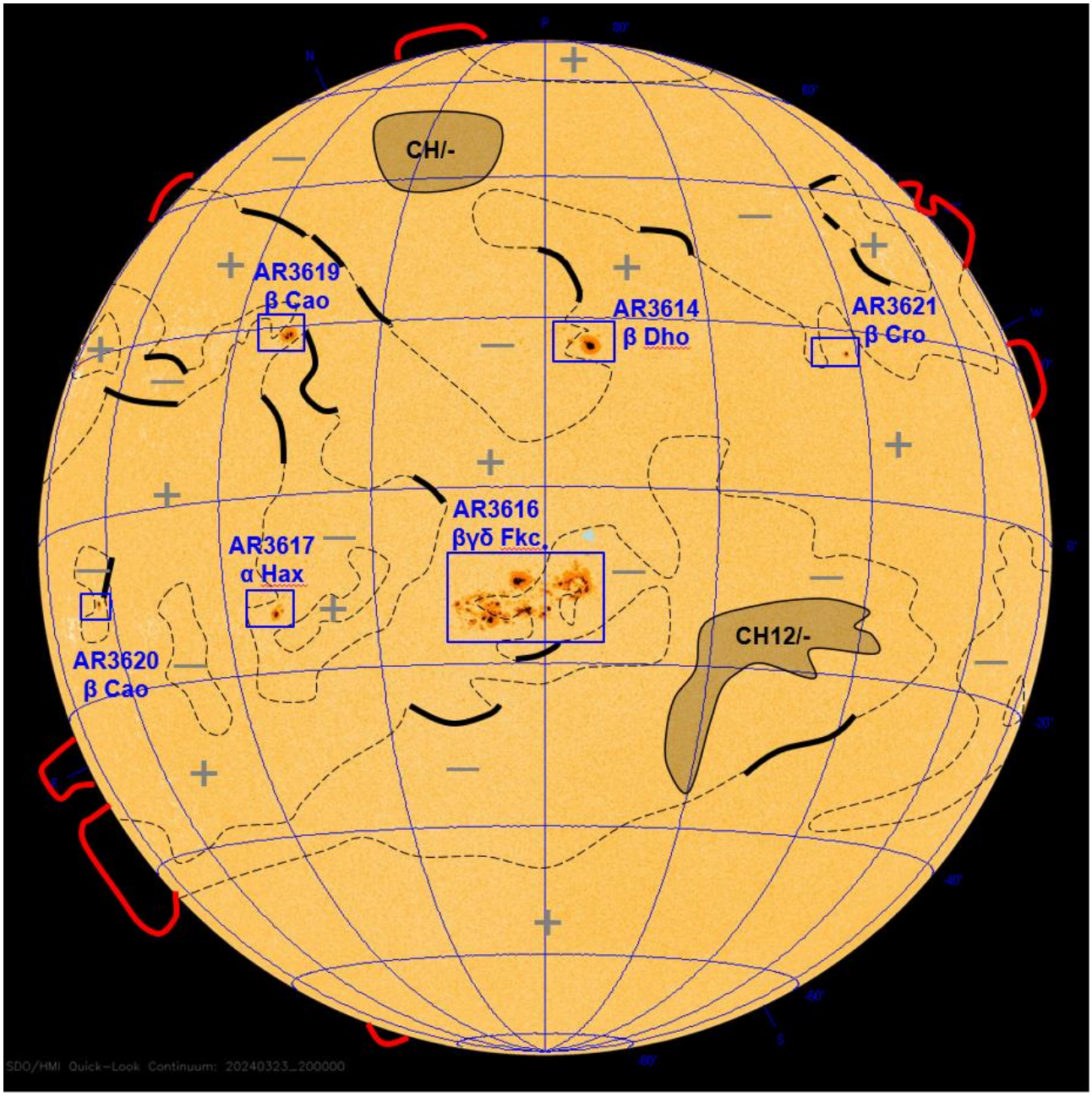
Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux at GOES18 is currently above S2 thresholds following X1.1 flare activity. Proton flux levels are likely to fall to S1 levels during Day 1 (23 Mar), before slowly falling back to background levels during Day 2 (24 Mar).

High energy electron flux (greater than 2MeV) is expected to persist at Normal Background levels at first, but may respond upwards towards the the end of the period given expected geomagnetic enhancement associates with the incoming CME and CH12/-. The associated 24-hour fluence is expected to persist below the Active threshold, but with an eventual slight rising trend possible.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

Figure 1. Solar Analysis Valid 24/0800UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

Geomagnetic Storms:

The is one Earth-directed CMEs in the current forecast, this is associated with the X1.1 flare a broad region north of AR3614 at 23/0133UTC. This produces a complex halo CME provisional modelled arrival late on Day 1 (24 Mar) or early Day 2 (25 Mar), with winds perhaps increasing to 550-600km/s before slowly declining.

The earth is now believed to be in the HSS in association with CH12/-, which has arrived slightly earlier than forecast and at time of writing giving elevated solar wind speeds of around 500 km/s. CH12/- is a persistent feature, with solar winds averaging around 450km/s observed on the previous rotation, along with an isolated G1 Minor Storm interval. Given the proximity of the equinox, similar coordinates and geometry of CH12/-, similar conditions are also likely on this occasion. In the absence of CME influence Slightly Elevated to elevated solar winds (450-500 km/s) would then be expected to persist into the new working week before beginning to ease through Day 3 (26 Mar) and returning to background levels by Day 4 (27 Mar).

Geomagnetic activity initially Unsettled to Active with a chance of G1-G2 intervals early Day 1 (24 Mar) due to coronal hole effects. Either late on Day 1 (24 Mar) or early Day 2 (25 Mar) G1-G2 minor to moderate geomagnetic storm intervals are expected with a chance of G3 strong geomagnetic intervals, given the expected arrival of the above CME.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	Yes	80	80	20	5
Strong	G3	No	30	30	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

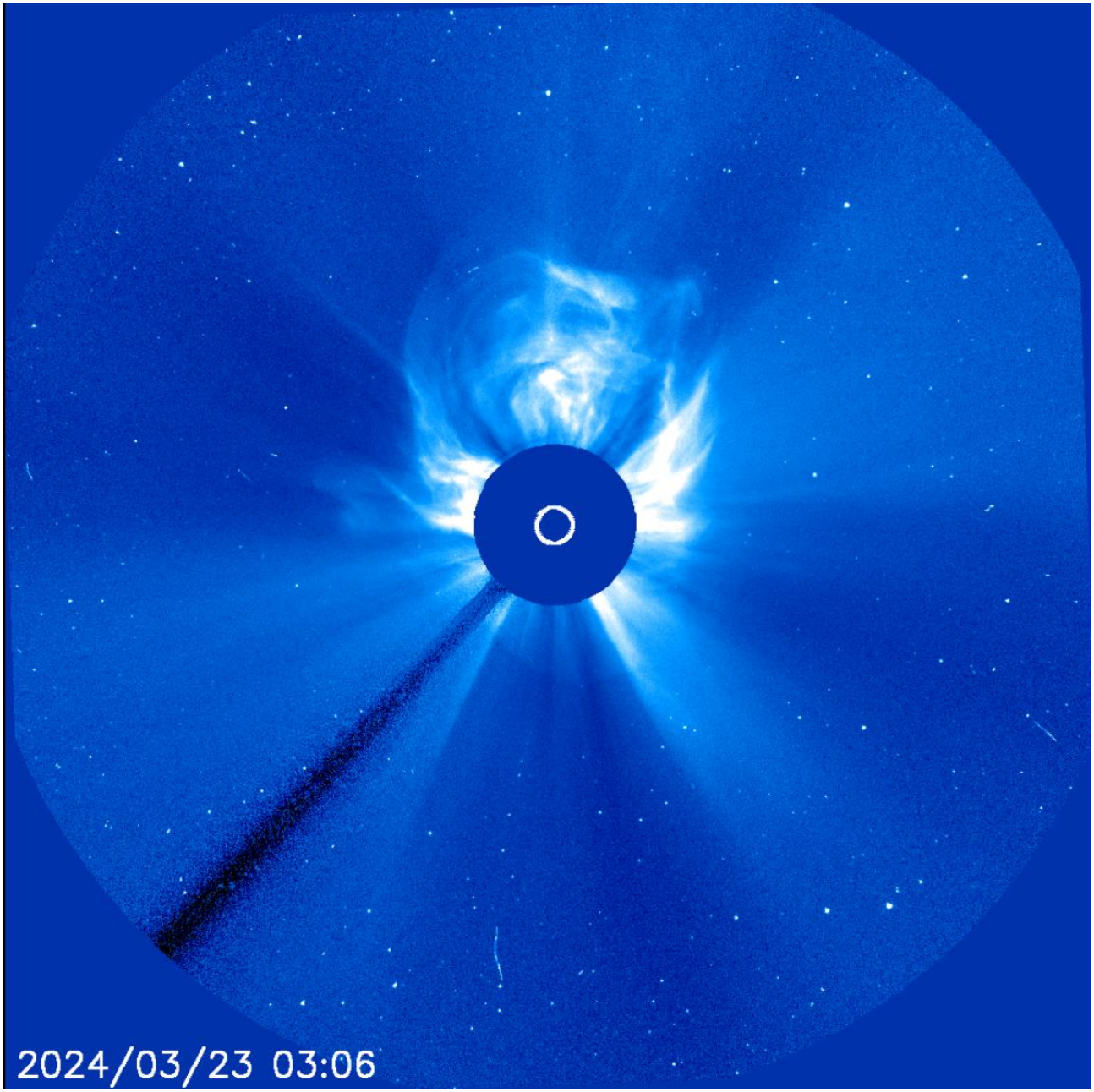
Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
23/0423	Full	AR3514	N	1178 km/s*	24/2300UTC +-07hr	CME timings fairly low confidence due to multiple sources of ejecta.

Figure 2: LASOC-C3 image showing broad halo CME with significant complexity and a northward bias.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

Space Weather Technical Forecast



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

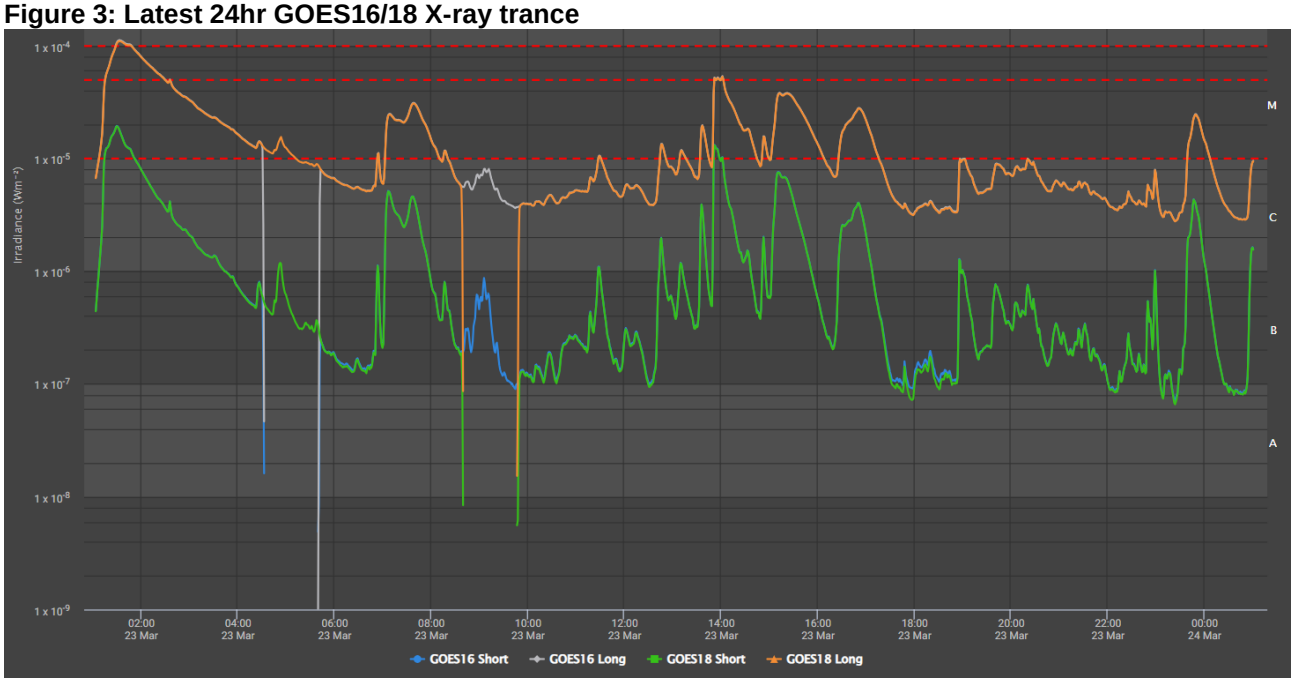
Radio Blackouts - X-Ray Flares:

The current Earth-facing disc is dominated in terms of activity by AR3615, and the most recent Penticton 10.7cm flux measurement is at a high for the rotation at 209sfu. AR3615 now comprises a large number of small umbrae, with significant mixing of its constituent magnetic polarities resulting in a Mt Wilson Beta-Gamma-Delta configuration. Ongoing darkening of the umbrae, along with emergence of further trailing spots and joining of the penumbral regions suggests a strengthening trend, in part demonstrated by the 5 M class flares we have seen over the past 24 hours, the strongest being an M5.1 at 23/1352UTC. The overnight X1.1 flare was primarily associated with AR3614, which remains generally stable and much more magnetically simple, though it lies within a large plage region.

Both AR3514 and AR3614 remains present throughout the four days of the forecast period, and while no significant sunspot regions leave in the same interval, there are now signs in EUV (AIA094 especially) that there may be a new oncoming region in the northeast to help bolster the risk of activity. All considered, further isolated M-class flares are likely on all days, with a level tendency, with a corresponding Slight Chance of X-class.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	70	70	70	70
Very Active	R3 to R5 X Class	Yes	20	20	20	20

Figure 3: Latest 24hr GOES16/18 X-ray trance



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

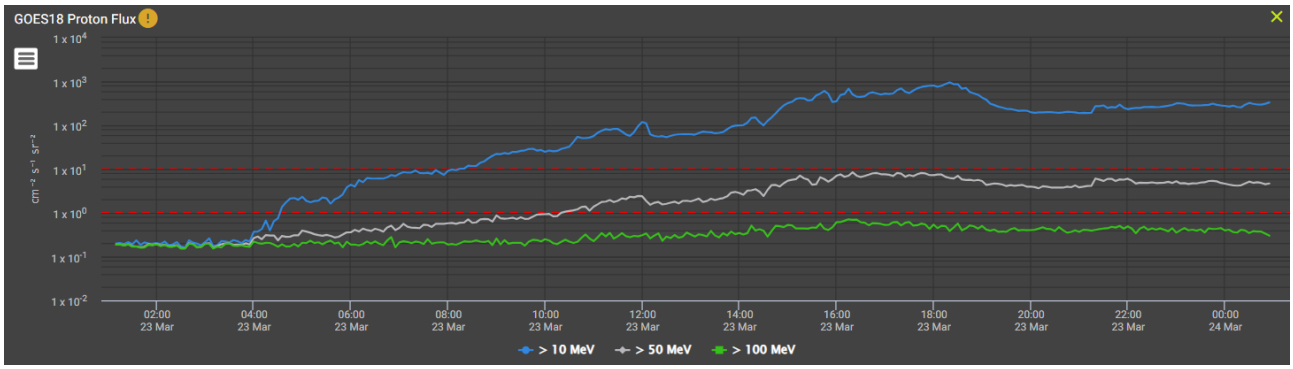
Solar Radiation Storms - (High Energy Protons):

High energy proton flux, as observed by GOES18 is currently at S2 levels following an increase associated with the X1.1 flare at 23/0133, reaching a peak of 956pfu at 23/1820Z. Since then it has been on a slow decline which is expected to continue in the absence of further significant flare activity. Levels are likely to fall to S1 levels during Day 1 (23 Mar), but may remain at S1 levels into day 2 (24 Mar) before slowly falling back to background levels. The dominant AR3615 will be making continued progress westward through this four-day period however to gradually increase the risk of S1 day-on-day in association with a new significant flare, with contributions from other regions generally paling in comparison at the time of writing.

It remains to be seen as to whether AR3615 has a tendency toward proton-rich flares, as any emanating from its current location near centre-disc are not in a prime location to connect.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	Yes	100	30	20	25
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: Latest GOES18 Proton trace



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.

High Energy Electrons Event (≥ 2MeV):

GOES16 high energy electron flux is expected to remain at Background levels from the next few days with the current connection with the HSS in association with CH12/- and CME impacts late Day 1 or early Day 2 (23-24 Mar). Once any associated geomagnetic activity eases, the electron flux at GEO is likely to rise to Moderate, with a Slight Chance of reaching High into the new UTC working week. This is low confidence however, as the main expected source, coronal hole CH12/-, is a largely persistent feature and no electron flux enhancement was observed on the previous rotation.

The most likely state of affairs is for the associated 24-hour fluence to remain below the Active threshold, with MOSWOC REFM providing generally good guidance. Fluence is likely to rise a little into the new UTC week, but only a Slight Chance of reaching Active fluence by the end of the period.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	10	20	20
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2024. All Rights Reserved.